NASA-TM-110799

7N-37-7M
60328
P. 9

NASA

AMES RESEARCH CENTER

Report No. R.A-001
Date 1/01/88
Prep.by AVERILL

SYSTEM ENGINEERING REPORT

SUBJECT: ALTERNATE AIR BEARING SIZES FOR SOFIA

PROJECT : SOFIA

DISTRIBUTION.: COPY

(NASA-TM-110799) ALTERNATE AIR BEARING SIZES FOR SOFIA (NASA. Ames Research Center) 9 p

N95-71621

Unclas

Z9/37 0060328

R.A-001
Averill.

ALTERNATE AIR BEARING SIZES FOR SOFIA

The baseline design for SOFIA's air bearing is a 48" diameter truncated sphere with a 31" diameter hole through the center. Since a bearing of this size presents serious concerns with regard to manufacturing, performance, cost, and weight, it is prudent to investigate the possible reduction in size were the requirement for the 31" hole relaxed.

Any bearing candidate must meet several functional criteria to be considered for replacement of the baseline design. Foremost among these is its ability to carry the loads without closing up the air gap. A commonly used parameter to quantify this is the eccentricity ratio:

$$e = (\text{delta})/c$$

Here, delta is the deflection of the ball under the given loading, and c is the gap size. Note that structural deformations are NOT included.

The spherical ball's air bearing performance has been evaluated using the same method of analysis applied to both the baseline design and the KAO bearing (Ref. 1), with the aid of the design charts of Ref. 2. The assumptions made were:

a) Supply pressure of 265 psia.

b) Telescope system weight of 20,000 lbs. This figure includes the telescope and counterweight but not the bearing weight.

c) Pressure differential of 9 psi across the bearing.

d) Rotor structure has been optimized such that its weight is equal to half of weight of a solid rotor.

e) Azimuth and LOS freedom of +-4 degrees; also a 2" wide annular tube mounting area is provided.

Figure 1 depicts the relationship between e_a (axial eccentricity ratio) and e_r (radial eccentricity ratio) for various values of R (outer radius) and r (inner radius). The maximum eccentricity (vector sum of e_a and e_r) for outer radii of 18,20,22 and 24 inches are plotted in Fig. 2a.

To choose a viable reduced size, we need to decide on a maximum acceptable value for the eccentricity ratio. Ref. 1 recommends that the gap never be reduced by more than 60%. However, Contraves Goerz tries to keep their gaps at least 50% of nominal. Bearing in mind (pun intended) that structural deformations and manufacturing inaccuracies will take up some of the gap, e(max) = 0.3 seems like a reasonable number. However, Contraves Goerz claims that the radial stiffness of this type of bearing is seldom more than 70-75% of that predicted. Another source (Speedring) reports empirical reductions in stiffness (in both directions) of about 20%. We will use e(max)=0.8 X 0.3=0.24.

The reduction in size is a bit disappointing. According to Fig. 2a, the minimum sphere diameter will be about 40", with a corresponding maximum hole size of about 16". Many of the manufacturing problems associated with the baseline design would probably not be substantially alleviated for this size ball. Figure 3 compares rotor size and weight (again with assumption (d) in effect). We can anticipate no reduction in weight when compared to the baseline design.

It is important to note the assumptions made when calculating the eccentricity ratios. Specifically, the system weight and rotor weight are not firm values. Figures 2b and 2c plot e(max) vs. rotor size for system weights of 30,000 and 10,000 lbs., respectively. The consequences of changes in system weight can easily be seen from these plots. For 30 kip, no geometry under consideration results in an e(max) less than or equal to 0.24. The lighter load of 10 kip allows a rotor size reduction to a 28" diameter with a 11.5" hole. Also, note that dynamic loads of up to 0.3 g's (unattenuated, worst case) have not been included in these numbers.

In addition to air bearing performance, the bearing must also function as a structural member of the telescope system. Finite element models of both the solid and stiffened 48" rotors indicate reasonable (less than 10% of gap) deformations. The first mode natural frequency of the entire system is also a concern. During the Phase A SOFIA study, a NASTRAN model of the system was built and subjected to a normal modes analysis. The resulting first mode prediction was 27 Hz, just above the design goal of 25 Hz. To gain an understanding of the effect of reducing the bearing stiffness, the model was analyzed with the stiffness of both the bearing and the attached support tube reduced by a factor of four. The resulting first mode was reduced to 22 Hz. Reducing the stiffness of only the bearing by a factor of four produced a first mode of 24 Hz. It would appear that reducing the size (and therefore the stiffness) of the bearing would have a limited effect on the system response.

In conclusion, the possible reduction in size of the air bearing seems to depend on:

a) Telescope system weight

b) Manufacturing constraints (accuracy attainable)

c) A "final" decision as to whether or not the 31" hole is a firm requirement

Rebecca Averill
M/S 213-4
X 4-4089

9/20/88

REFERENCES

1) Bouvier and Schmertz, "A Spherical Gas Bearing for Airborne Application", ASLE Transactions, Vol. 18, pp. 15-20

2) Mechanical Technology Inc., "Design of Gas Bearings", @ 1972, MTI, Vol. I and II

FIG. 1 Axial and Radial Eccentricities
System Weight = 20 Kip

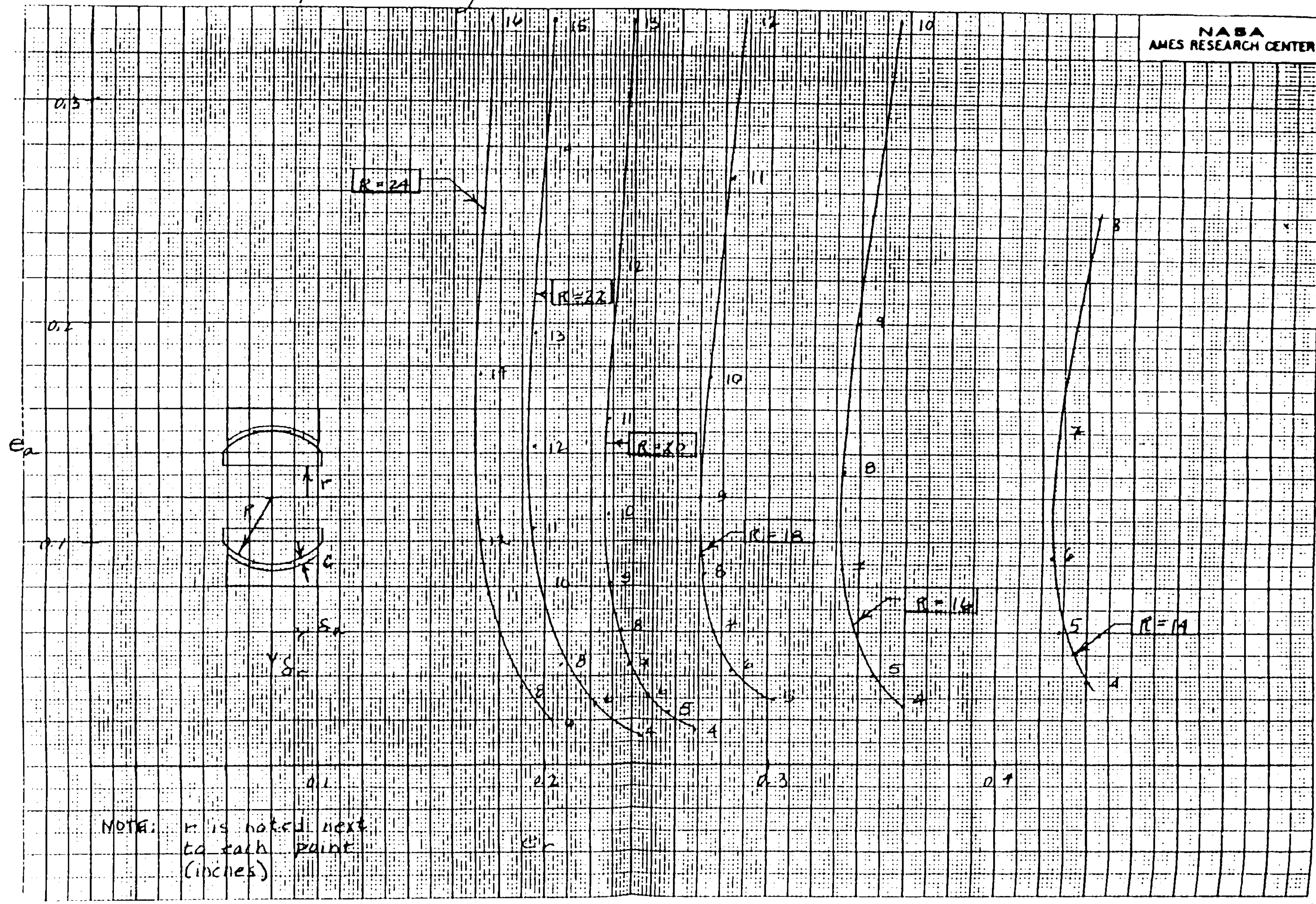

FIG. 2a Maximum eccentricity vs. hole size
System Weight = 20,000 lb.

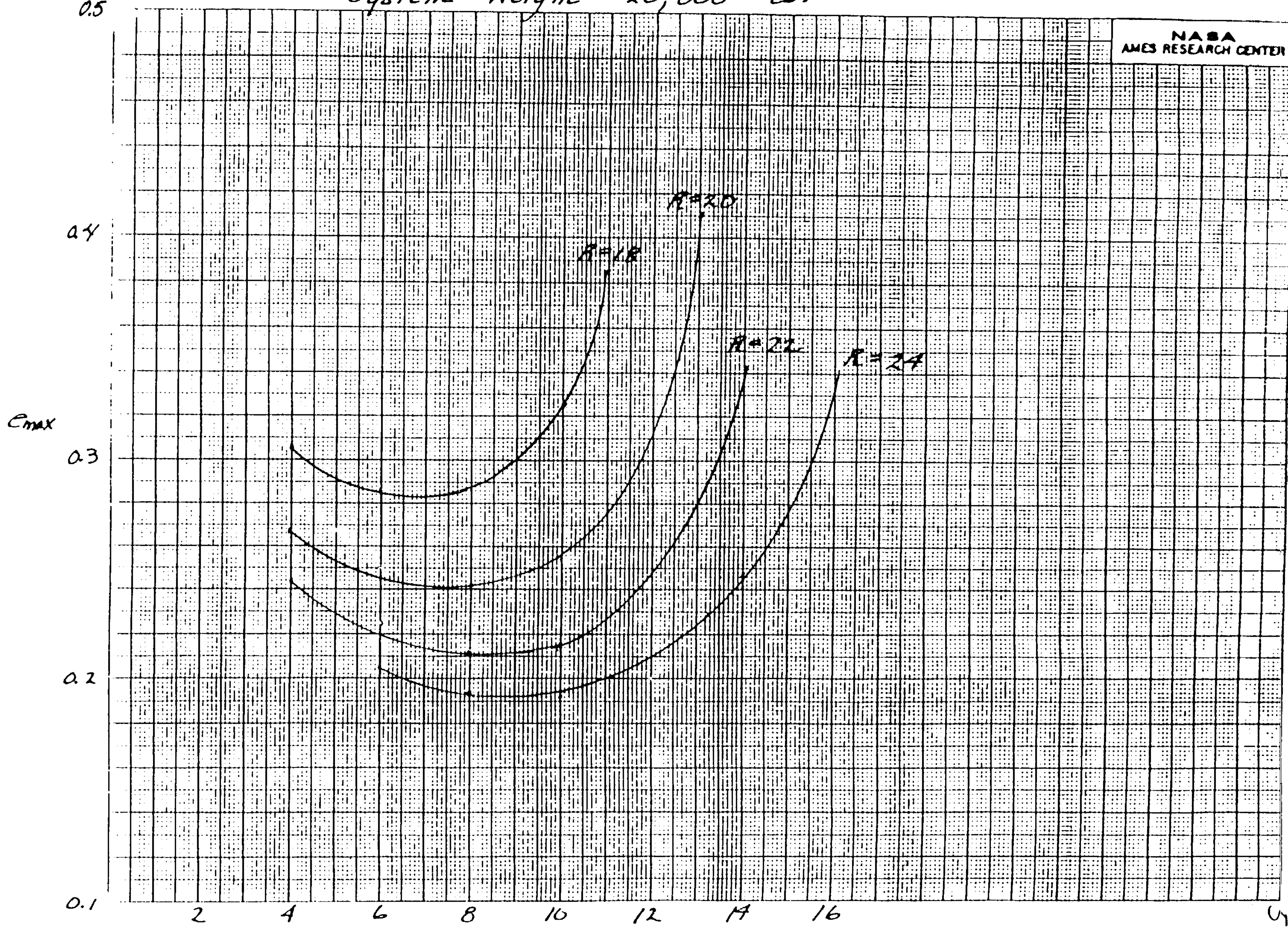

FIG. 2b Maximum eccentricity vs. hole size
System Weight = 30,000 lb.

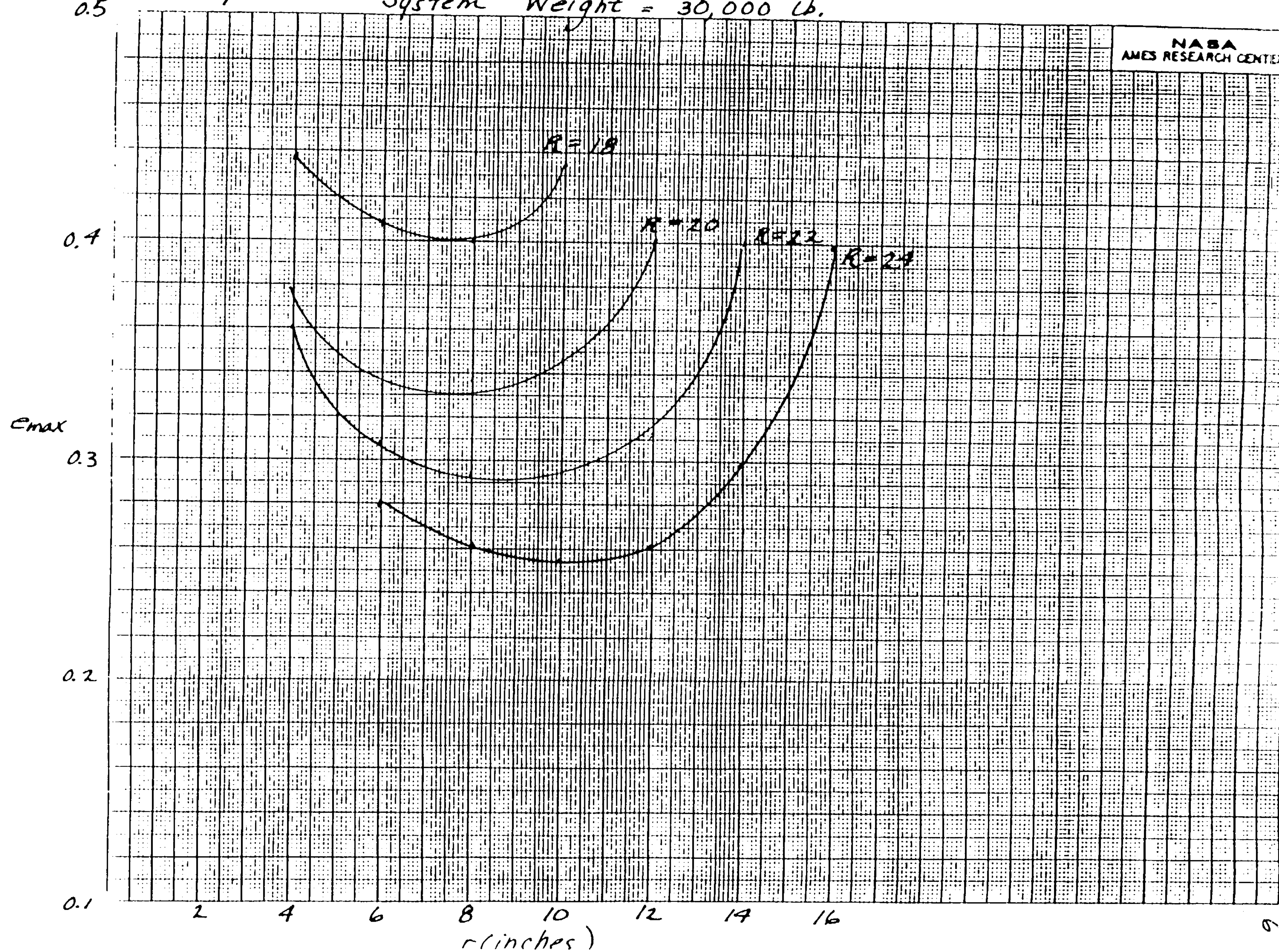

FIG. 2c Maximum eccentricity vs. hole size
System Weight = 10,000 lb.

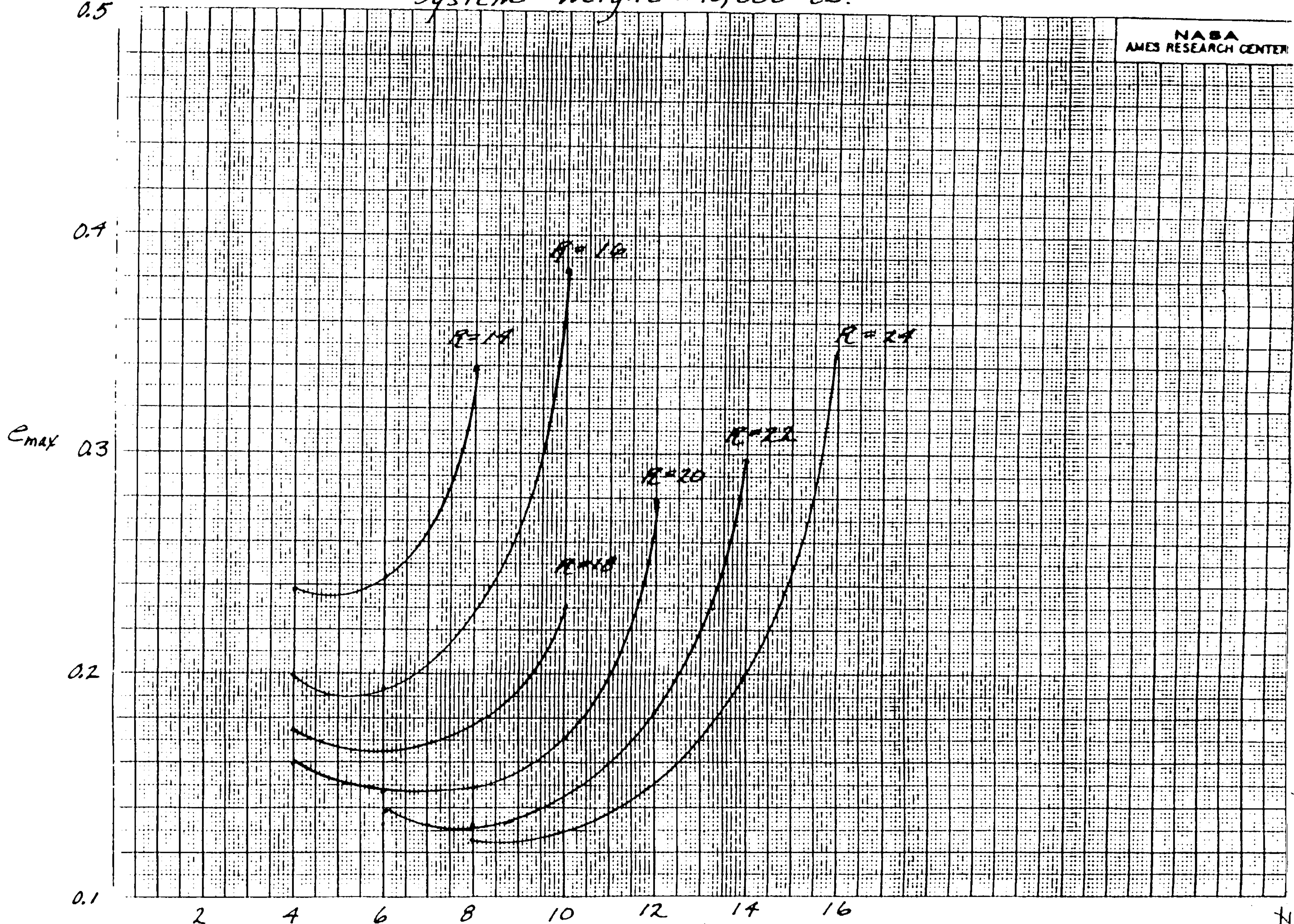

FIG. 3 Weight of Rotor Vs hole size